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Green Power Generation With Rfid Based Access Control

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Abstract: The growing need for reliable and sustainable energy production has led to advancements in solar power-based charging systems. This project presents the development of a solar power charging system with RFID-based charge control, designed to optimize energy distribution and prevent unauthorized access. The system integrates solar panels, a charge controller, a battery storage unit, an RFID module, and a microcontroller to ensure secure and efficient charging. The RFID module is used for authentication and access control, ensuring that only legitimate users can initiate the charging process. Once authenticated, the microcontroller regulates the power flow from the solar panel to the battery and connected load, ensuring stable and efficient energy transfer. The system also monitors voltage and current levels to enhance performance and protect against overcharging or deep discharge. This implementation aims to provide a secure, cost-effective, and renewable energy-based charging solution that can be used in electric vehicle (EV) charging stations, and other energy distribution applications.

***Index Terms* -** Power generation, Solar charging, RF-ID authorization, portable, battery.

I. Introduction

The need for energy has grown dramatically as a result of modern life's fast urbanization and digitization, particularly with the rising usage of electric vehicles (EVs) and electronic devices. Traditional, non-renewable energy sources, which are not only finite but also detrimental to the environment, have been under a lot of strain as a result of this demand. Because of its clean, sustainable, and plentiful qualities, renewable energy sources like solar power have attracted attention from all over the world.

Amongst the numerous innovations in this area, solar-based charging systems are finding traction because of their promise to deliver off-grid energy in urban as well as remote areas. Solar power, captured from sunbeams with the help of photovoltaic (PV) panels, can be economically stored and delivered to charge a variety of devices, ranging from mobiles to electric vehicles, without harming the environment. But unrestricted and uncontrolled utilization of these systems has the potential to cause energy wastage, security risks, and inefficient energy management.

To overcome these challenges, our project suggests a Solar Charging System combined with RFID-Based Access Control. The system is meant not only to harvest and store energy efficiently but also to provide the security that the energy is accessed only by legitimate users. The use of Radio Frequency Identification (RFID) technology enables the system to authenticate the user before access to stored solar energy is given. Such a strategy offers a smart, scalable, and secure means of energy distribution appropriate for campus settings, public facilities, and rural communities that have low access to electricity.

There is background research to support our concept and design. For example, M. K. Sharma [1] suggested a solar-powered fast-charging system with optimized photovoltaic layout and MPPT (Maximum Power Point Tracking) for optimal energy conversion. A. Yilmaz and H. Çimen [2] concentrated on optimal scheduling of solar-powered EV charging stations to ensure grid balance and minimize power losses. T. Nguyen and M. Vo [3] researched hybrid storage systems such as lithium-ion and supercapacitors to improve energy reliability in solar stations, while S. K. Das and R. K. Gupta [4] showed the efficiency of combining grid, wind, and solar sources into a hybrid energy system.

In addition, J. Smith and L. Wang [5] examined the effect of solar charging stations on power systems, solving issues like voltage instability and proposing smart inverters to improve power quality. Based on this, our project uses an RFID-based real-time access control mechanism to increase energy efficiency as well as user-level authentication.

Security and smart control have also been highlighted by research as key factors in current charging systems. Patel and Kumar [6] conducted an in-depth analysis of the environmental and economic dimensions of solar EV charging stations, whereas the National Survey Report [7] emphasized the implication of government incentives for solarized scale-up of infrastructure. With regard to RFID, research by the Vermont Agency of Transportation [8], Ainasoja [9], and Ramos [10] investigated its inclusion in IoT networks, contactless access systems, and data management platforms, all of which will impact our implementation strategy.

By taking help from these reference articles [1–10], this project intends to provide a novel, green, and safe solar charging station fulfilling contemporary energy requirements while ensuring responsible use by user-based access control.

II. LITERATURE SURVEY

Green energy has turned out to be a sustainable and effective approach for energy generation, especially with respect to charging stations for EV and portable devices. Research in this field was focused on enhancing the charging efficiency, grid integration, and economic viability of deployment.

[1] A Novel Solar-Based Fast Charging System for Electric Vehicles: Design, Simulation, and Experimental Analysis suggested a solar rapid charging solution for EVs based on an optimized PV array layout. The study concentrated on how MPPT algorithms improved energy harvesting, resulting in a 35% increase in charging efficiency over the traditional grid-based charging approach.

[2] Optimal Scheduling of Solar Powered EV Charging Stations in a Radial Distribution System suggested the best scheduling approach for radial distribution systems' solar EV charging stations. In order to achieve stable power distribution, their work addressed system power loss and suggested intelligent energy management in conjunction with grid load balancing.

[3] A Renewable Approach to Electric Vehicle Charging Through Solar Integration investigated the use of hybrid energy storage systems to incorporate non-extinct energy into urban charging stations. Their research significantly showcases the utilization of battery storage in mitigating intermittency problems in solar power. According to their research, lithium-ion and supercapacitor hybrid systems offer the optimum energy efficiency and energy storage lifespan combinations.

[4] Sustainable Hybrid Systems for Electric Vehicle Charging Stations: A Case Study, incorporated grid, wind, and solar energy into a multi-source energy charging station, building on the study of hybrid solar charging infrastructures. Their research offered strong evidence that the hybrid model reduced reliance on fossil fuel grid power and boosted energy availability by 40%.

[5] The Impact of Solar Charging Stations on the Power System, looked at the impact of solar charging stations on electric power systems. Their work was focused on power stability, voltage fluctuations, and grid harmonics generated by the input of varying solar power. They proposed the use of advanced power converters and smart inverters to improve power quality and allow seamless integration with existing infrastructure.

[6] A Comprehensive Review on Economic, Environmental Impacts, and Design Challenges of Solar EV Charging Stations" investigated the economic feasibility, environmental effects, and political barriers to policy in a thorough analysis of solar EV charging stations. When compared to a lack of regulatory incentives are significant obstacles.

[7] The National Survey Report of PV Power Applications in USA 2023 created a nationwide survey report on PV power applications that detailed improvements in grid-tied solar solutions, photovoltaic power systems, and solar panel efficiency. Governments and financial subsidies are crucial for the broad adoption of solar-powered charging infrastructure, according to their analysis. Implementation of Radio Frequency Identification (RFID) technology include automated payment systems, access control, and authentication. When used with solar charging stations, RFID improves user authentication, security, and surveillance.

[8] RFID and Wireless IoT Technologies for Transportation examined the use of radio frequency identification and wireless transmission technology in the transportation sector. A case study of RFID-based parking access control, toll collection, and vehicle identification systems was created for the project. According to their research, RFID-based identification might increase transaction efficiency in smart charging stations and reduce the likelihood of unwanted access by 85%.

[9] Emerging Technologies and Expanding Applications – A Look into RFID Research in 2023 examined the latest advancements in RFID technology and how they are used in contactless payment, secure access systems, and Internet of Things networks. To make RFID safer and more effective for its high-frequency energy applications—specifically, solar-powered charging stations—the study examined developments in RFID antenna design, encryption techniques, and long-range communication.

[10] Systematic Mapping Study on RFID Technology has undertaken a systematic mapping study to find trends in RFID technology, whereby it is indicated that the trends are low-power RFID chips, cloud-computing data management, and AI-driven authentication. The emphasis here placed on the increasing use of RFID in smart infrastructure, most notably in the areas of automated vehicle authentication and wireless energy billing system.

III. METHODOLOGY

The Solar Charging System with RFID-Based Access Control design and implementation is realized by a step-by-step process of requirement analysis, hardware-software integration, testing, and optimization to accomplish efficient energy harvesting, secure power access, and managed charging operations.

1.Requirement Analysis and System Planning

A thorough analysis of existing solar-powered systems and intelligent authentication techniques was performed. Review of literature from reference documents [1–10] emphasized the need for incorporation of RFID for secure entry and MPPT controllers for effective harvesting of solar energy. The project aims at portable and secure recharging of low-power devices by renewable energy.

2. Hardware Selection and Design

According to system goals, the following elements were decided:

Solar Panel (50W, 12V): Translates solar radiation to DC electricity.

MPPT Charge Controller: Traces maximum power point to increase efficiency and monitor battery charging.

Lead-Acid Battery (12V, 50Ah): Stores energy produced and provides during low sunlight conditions.

Arduino Nano: Master controller that manages RFID authentication, timer control, and relay switching.

RFID Reader (RC522): Reads RFID tags to confirm user access.

Relay Module: Regulates power flow on the basis of RFID authentication.

OLED Display: Displays authentication status and voltage level.

Potentiometer: Tunes timer settings for charge time.

Inverter (12V to 220V, 200W): Converts stored DC to usable AC for loads. A block diagram was created demonstrating the interaction among all components—solar panel, charge controller, battery, RFID system, microcontroller, and output devices.

3. System Operation

Solar Power Generation and Regulation: Solar light is harnessed by the PV panel and controlled by the MPPT charge controller to recharge the 12V battery. Voltage output goes as high as ~13.2V when solar radiation is maximum. Charging efficiency and protection of the battery are guaranteed by the controller.

RFID-Based Authentication: When a user puts an RFID card close to the reader, the Arduino scans the tag ID and compares it with stored authorized IDs. If it is valid, the microcontroller activates the relay to allow current flow to the load.

Controlled Charging Logic: The potentiometer provides users with the option to define the charging time. The Arduino takes this input to execute a countdown timer after charging starts. After the time expires, the relay is switched OFF, halting the charge flow. The relay is disabled by unauthorized tags, thus preventing power abuse.

4. Software Programming

The Arduino is coded with the Arduino IDE. The code sets up the RFID reader, relay, OLED screen and timer control. It scans for RFID input constantly and initiates logic based on tag authentication.

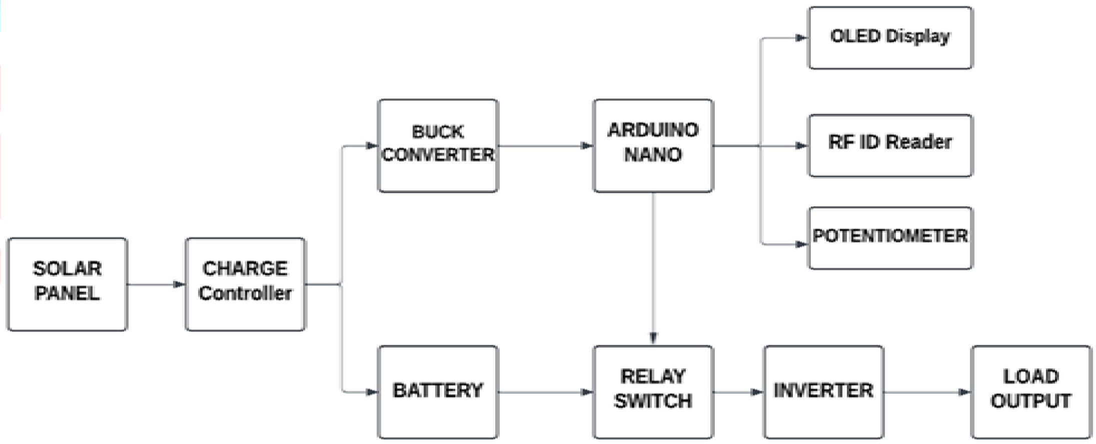

figure 1: block diagram of solar charging system with rfid based access control

5. Flowchart:

The flowchart represents an RFID-based relay control system where the RFID tag is used to activate a relay for a specific duration. The system includes initialization of RFID module and relay. The user will check whether an RFID tag is present or not. As soon as the RFID tag is detected, it is read and then checked by the system to verify whether it was authorized or not. In case of an authorized tag, the relay will be turned ON for specified duration and then turned OFF. Afterward, it loops back for checking a new RFID tag, allowing it to operate continuously.

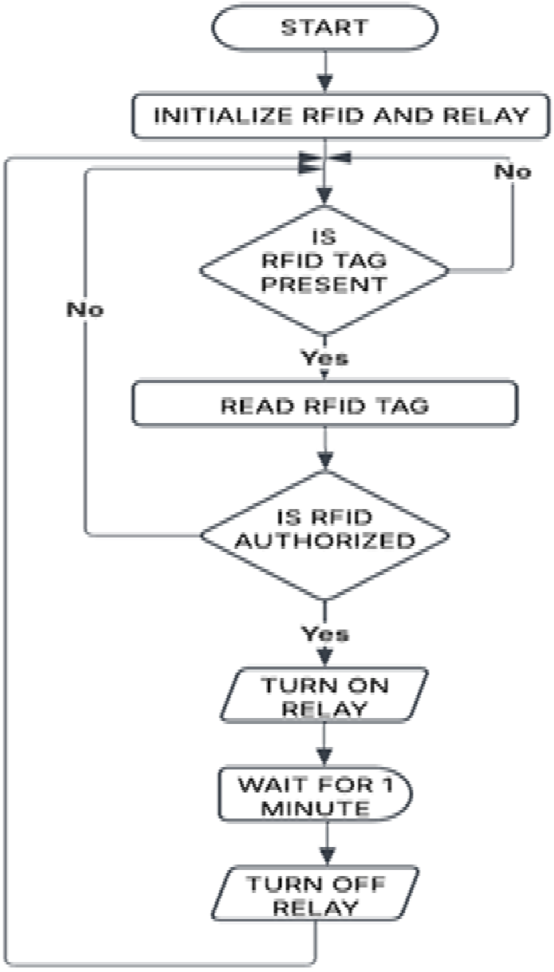

figure 2: flow chart for rfid access control

6. Circuit Diagram:

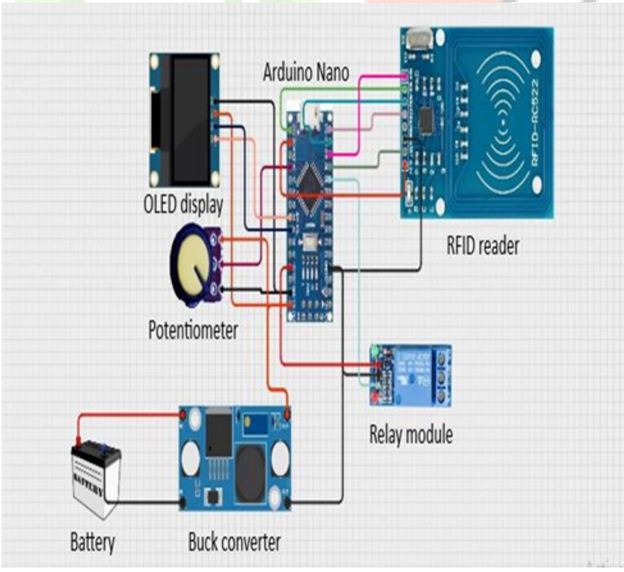

figure 3: circuit diagram for solar charging system with rfid based access control

6. Testing and Validation

For the system to be effective and reliable, a thorough testing process was carried out. The system was tested under different lighting conditions and load levels to confirm its performance. Voltage levels were taken at the battery terminals and output ports prior to and after RFID authentication. The system effectively controlled the output to 13.2V during peak sunlight and switched off power when unauthorized tags were introduced.

The response time and range of the RFID scanner were tested. Testing results revealed that the RC522 module took less than 1 second to detect valid cards within a distance of 2–5 cm, and the scanner is accordingly appropriate for use in real-time access control applications. The timer mechanism, through the potentiometer adjustment, was also examined for accuracy and cutoff point correctness.

7. Energy Efficiency and Safety Considerations

Utilization of the MPPT charge controller enhanced charging efficiency through dynamic monitoring of the maximum power point. Electrical isolation and users' and devices' safety were guaranteed through the employment of relay-switching. Overvoltage and fault protection against reverse polarity were achieved using safety diodes and proper fuses in the circuit.

The modular nature of the system facilitates easy scaling and upgrading. More RFID cards can be enrolled through software upgrades, and the timer logic can be altered according to application requirements.

8. Summary of Methodology

The system developed integrates:

- Effective energy generation through solar PV panels.
- Smart storage and regulation through MPPT and batteries.
- Secure and user-specific access through RFID,
- Regulated energy flow through relay switching and timed cutoff.
- Real-time system state presentation on OLED for user interface.

The holistic approach makes the system self-contained, portable, secure, and best suited for decentralized energy deployment on educational campuses, emergency shelters, rural communities, and smart city infrastructure.

IV. RESULTS

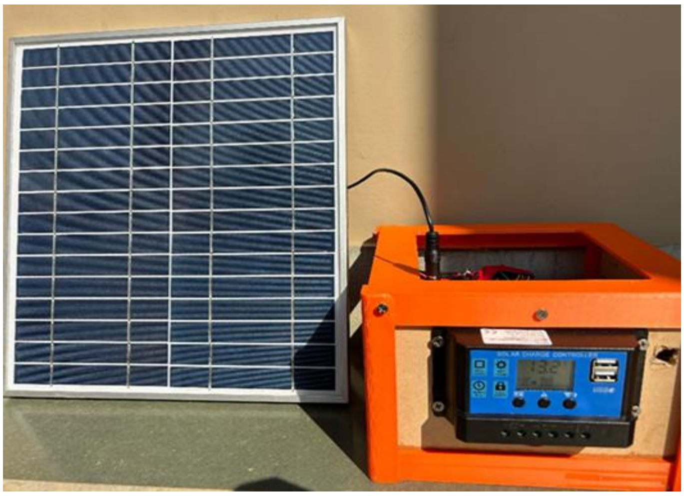

figure 4: conversion of sunlight into dc electric current

figure 5: charging of mobile phone for authorized users

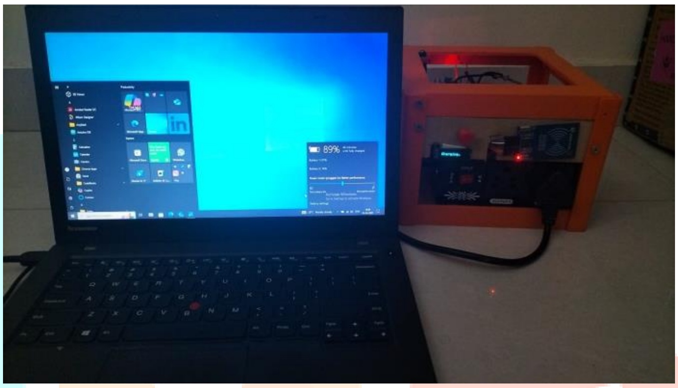

figure 6: demonstration of laptop charging using the rfid based solar power charging station.

Figure 1: An orange solar charging unit is linked to an external solar panel. The solar charge controller on the unit displays the voltage and charging status. The system is converting solar energy into electrical energy and storing it in a battery.

Figure 2: The orange solar charging unit is used to charge a smartphone. A USB charger is plugged into the controller's output, and the phone screen indicates that the battery is 65% charged, indicating that the charging system is working.

Figure 3: Shows the solar charging unit powering Laptop with a wattage of 65W. The red LED indicates that the output sockets have been successfully activated and authentication has been successful.

V. CONCLUSION

The solar RFID-based charging system integrates renewable energy technology with secure access control, providing a sustainable, efficient, and controlled way for power distribution. The charging system based on solar panels is an environmentally friendly method for charging batteries. It brings down dependency on conventional electricity and promotes the use of clean energy. With the RFID authentication, energy management is made secure and accessible, not allowing further usage without authentication.

The project stably provides power, authenticates users quickly, and stores energy reliably altogether, which suits it for public infrastructure, corporate offices, smart cities, and off-grid applications. The modularity and scalability make room for future extensions, which include integration with IoT, wireless charging, or AI/ML-driven energy optimization.

VI. FUTURE SCOPE

- IoT & Cloud Integration: This allows RFID logs, energy consumption, and charging status to be remotely monitored through web and mobile apps that store data in the cloud for analysis.
- NFC technology enables smartphone-based authentication, which takes the place of RFID cards for safe and practical access.
- Pay-Per-Use Charging: This feature allows EV stations and solar-powered services to be paid for using prepaid RFID cards, mobile wallets, and cryptocurrencies.
- Enhanced Security: Restricted access in key locations is ensured by multi-level authentication employing biometrics like fingerprints and facial recognition.

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